Presence

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1.0 INTRODUCTION

If one wants to turn virtual reality (VR) technology into an effective tool, it is vital to obtain a basic understanding of the key elements for success. A concept that has received a lot of attention from VR researchers is presence. Presence may be loosely described as the feeling of 'being there' in the virtual world instead of just experiencing stimuli from displays [3] (for a clear description of the difference between presence and immersion, refer to Slater [10]; immersion is defined as the extent to which the actual system delivers a surrounding environment, one which shuts out sensations from the 'real world', which accommodates many sensory modalities, has rich representational capability, and so on; the term system immersion may be used for this, as opposed to an immersive response such as presence). Letting a user feel presence in a virtual world might be a goal in itself, but it has often been suggested that presence is a necessary element to reach higher goals. For instance, some researchers claimed that by developing an understanding of the factors that drive presence, their interrelationships, and how they relate to human performance and after-effects, a set of design principles could be specified that should lead to enhanced human performance in VR systems [15]. This chapter presents an overview of research on presence, i.e., theories, definitions, and multi-dimensionality (Section 2), effects (Section 3), measurement (Section 4), and determinants (Section 5). Section 6 contains some concluding remarks.

2.0 THEORIES, DEFINITIONS, AND MULTI-DIMENSIONALITY

Several theories have been proposed on the nature of presence in VR. Schuemie et al. give an extensive review of different conceptualizations, definitions and theories with regard to presence [8]. Here, the most influential ones will be discussed. An important theory on presence is based on a definition of Lombard and Ditton, who define presence as the 'perceptual illusion of non-mediation', i.e., the extent to which a person fails to perceive or acknowledge the existence of a medium during a technologically mediated experience [5]. Although a user knows that an experience is mediated and can distinguish between mediated and direct stimuli, at some level, the illusion of non-mediation can be perceived. Another,

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somewhat similar, commonly used definition is that a user feels present when he or she is engaged to the point of 'suspending disbelief' in what he or she is experiencing [9]. Again another viewpoint emphasizes the exclusiveness of presence by arguing that an individual can only feel present in one environment at a time. Presence may oscillate between the real, virtual and internal (or imaginable) world. In this case, the level of presence experienced in a VR simulation depends on the amount of time being present in the virtual world. Witmer and Singer have related presence in part to the allocation of attentional resources [19]. It is argued that by focusing more attention to an environment a user will get more involved and as a result get a higher sense of presence. In a practical approach to the exclusiveness theory, Slater considered presence as a perceptual mechanism for selection between alternative hypotheses based on Gestalt psychology [11]. When engaged in a VR simulation a user may be receiving competing signals from several different environments. Moment by moment, a selection mechanism organizes the streams of sensory signals into an environmental gestalt. Sensory data relevant to other environmental gestalts are relegated to the background. Given these competing signals, at any moment action is chosen on the basis of selection between alternative hypotheses, alternative interpretations. The presence selection mechanism is an answer to a fundamental question: "Where am I?" Slater claims that the environment hypothesis is continually reverified or else a break in presence (BIP) occurs. A BIP is the moment of switch between responding to signals with source in the virtual environment to those with source in the physical or internal environment. Finally, several researchers made an effort to explain presence as part of bigger theories that describe how human beings make sense of the world around them [8]. They acknowledge the role of a human being as interpreter, making a mental model that estimates reality. It is theorized that humans conceptualize their environment in terms of the actions that can be taken on it. In predicting the outcome of actions, humans can suppress certain contributions, thereby creating a self-consistent representation despite conflicting features. Actions that are successfully supported by the environment lead to presence. Actions are supported when they are lawful, i.e., similar to the real world in which our perceptual system evolved.

There is a growing awareness that presence is a multi-dimensional concept, i.e., there are several different types of presence [3, 4, 5, 16]. In this sense, presence might be compared to a concept like emotion, of which existence of different dimensions is well established (e.g., instead of having one scale to express the 'amount of emotion' of a person, a distinction is made between anger, happiness, surprise, etc.). So, efforts have been put in trying to discriminate between the different dimensions of presence that exist. Several dimensions have been proposed, but are likely to be overlapping or non-orthogonal to some extent. First of all, a distinction must be made between physical presence and social presence as mentioned by IJsselsteijn et al. [3] and IJsselsteijn and Riva [4] basing their work on the findings of Lombard and Ditton [5]. Physical presence refers to the sense of being physically located in mediated space, whereas social presence refers to the feeling of being together, i.e., of social interaction with a virtual or remotely located communication partner. A clear distinction between these two is that the ability to communicate is essential for social presence, but not for physical presence. Co-presence can be defined as being together in a shared space, combining characteristics of physical and social presence [3, 4]. Schubert et al. [7] and Regenbrecht and Schubert [6] showed that items assessing subjective experiences of physical presence can be split into three different components:

1) Spatial presence, i.e., the human mind understands the relationship between the body and the environment in terms of distance, direction, size, etc.
2) Involvement, i.e., the attention distribution between internal, virtual and real world.
3) Realism, i.e., whether the virtual world seems as "real" as the real world.

The multi-dimensionality of presence is outlined in Figure 3-1.

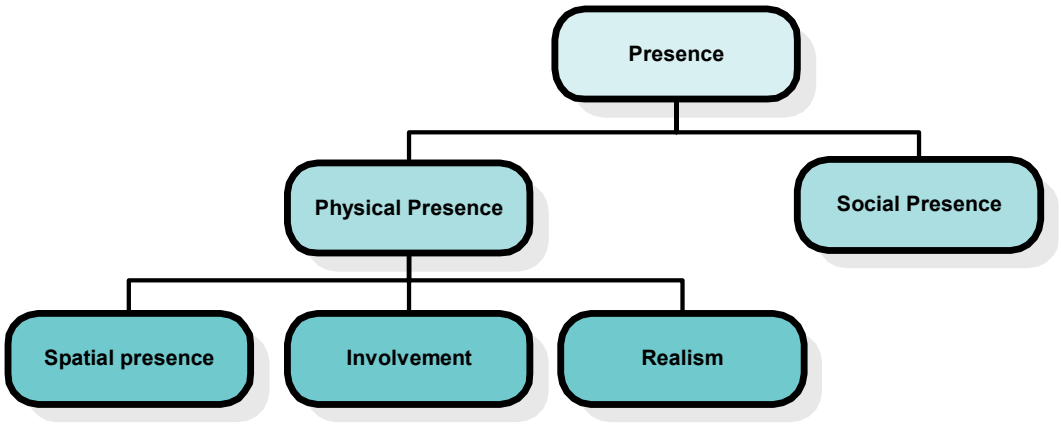

Figure 3-1: Dimensions of Presence.

3.0 EFFECTS OF PRESENCE

For many VR experiences, full presence is not necessarily required for the application to be useful [9]. For instance, when an application's goal is to explore a database, a high level of presence may not be necessary, possible, or even desirable. The degree to which presence is desirable for a particular experience varies based on the goals of the experience. If the experience's success is based on how engrossed the participant becomes, presence plays a key role in the experience's fulfilment.

It may be argued that for most entertainment applications, creating a compelling sense of presence is a desirable goal [3]. However, for other application areas this may be less straightforward – e.g., with certain tasks, changes that may diminish presence may in fact enhance performance. Regenbrecht and Schubert argue that training relies on a transfer of learning from the virtual to the real world, and think that it is facilitated by a high realness (a component of presence) of the virtual world [6]. Witmer and Singer suggest that many of the same factors that increase presence are also instrumental in promoting learning and performance [19]. Thus, they believe virtual environments to be used for entertainment or for training should be designed to induce high levels of presence for most tasks.

Schuemie et al. in their review describe the following four potential effects of presence [8]:

1) The subjective sensation of presence; this can be a goal in itself for certain applications.
2) Task performance; although there is a strong belief that there is a positive correlation between presence and task performance, it remains controversial whether presence actually contributes to better task performance [8, 15]. It is very likely that this relationship depends on the characteristics of the task that the user has to perform. In the case where the task was to train for a real world situation such a positive correlation is deemed likely [5].
3) Physical responses and emotions; these are supported by more empirical evidence. The problem remains however that only weak evidence for certain relationships have been found and the question of causality has often not yet been addressed.
4) Simulator sickness; the relationship between presence and simulator sickness has been investigated, with contradicting results presented in different papers [8, 15, 19].

Schuemie et al. [8] and IJsselsteijn et al. [3] conclude that much uncertainty remains as to the usefulness of presence. Sherman and Craig suggest that presence assists in creating a sense of faith in the user that the world is consistent beyond what is immediately presented, e.g., that the world includes events that are presumed to have occurred and places that are presumed to exist [9].

4.0 MEASUREMENT OF PRESENCE

A good measurement technique of presence assists developers to enhance VR systems that have the intention to invoke a sense of presence in its users. It may also aid human factors specialists in investigating relationships of presence and other measurable entities, like for instance task performance. Moreover, by addressing the issue of how to measure presence, greater understanding of the factors that drive this phenomenon may result [3, 15].

A measurement technique for presence should satisfy the basic rules that apply to all measuring techniques. It should be repeatable, reliable, robust, and sensibly correlated with measurable characteristics of a VR system. Due to its psychological aspects, most measurement techniques of presence are derived from measuring methodologies used in psychological research [15]. For instance, rating scales or equivalence classes (e.g., "On a 1 – 10 scale, rate the amount of presence this VR system produces for you"), method of paired comparisons (e.g., "Which of these two VR systems produces the greater amount of presence for you?"), or cross-modality matching (e.g., "Make this light as bright as the strength of the presence you experienced in this VR system").

One of the biggest problems with current measurement techniques for presence is that a single, accepted paradigm for the assessment of presence is lacking. As a consequence, a variety of presence measures has been proposed [3]. These presence measures are based on different assumptions on the nature of presence. Without consensus on one such paradigm, it is difficult to compare presence among research groups to assess the relative efficacy of different VR systems.

An important development in measuring techniques for presence is the monitoring of BIPs [11, 12]. Because of its definition there is a straightforward relation between BIPs and presence. Slater has developed a stochastic model that estimates the tendency that a user is in a presence state during an experience based on the reported BIPs [11]. Results of experiments using this method are promising.

Despite the lack of consensus, the reported measuring techniques of presence can be classified into two distinct categories: subjective measurement and objective measurement. It seems likely that both subjective and objective tools will be required for the comprehensive measurement and understanding of the sense of presence [15].

4.1 Subjective Measurement

All subjective measurement methods are characterized by the fact that the user him/herself has to report on the amount of presence that is experienced. Some researchers argued that 'subjective report is the essential basic measurement' of presence [3]. Stanney et al. say that subjective assessment of VR systems is thought to be particularly useful in early evaluation and exploration phases [15].

There are several techniques that require a user him/herself to report on the amount of presence. The majority of all studies measure presence through post-test questionnaires and rating scales, which have the advantage that they do not disrupt the experience and are easy to administer [3]. Several questionnaires have been published, each of them created from a different point of view, and with different applicability. The most influential questionnaires, referred to as SUS6, PQ, IPQ and ITC-SOPI, are all reviewed by Schuemie et al. [8].

Although usage of post-test questionnaires is the most common means of presence measurement, there are disadvantages associated with this method. For instance, Slater [11] states that presence in VR systems reported via questionnaires is usually high, especially relative to the paucity of the virtual world compared to the real world. He refers to an experiment which reported that presence in a virtual office was the same as for a real office [18]. Furthermore, ambiguous and erroneous interpretations of questionnaire questions

will not all be exorcised by pilot experiments [17]. Questions require great care. Oral debriefing of users resolves many ambiguities.

Another limitation of discrete post-test subjective ratings is that they do not provide any measure of temporal variations in presence [3]. Such variations are likely to occur through changes in the stimulus (i.e., both in VR system hardware components and the virtual world) or the participant (e.g., prolonged exposure may have an impact on presence through perceptual-motor adaptation, boredom, fatigue, etc.) and would be lost in an overall post-test presence rating. In addition, discrete subjective measures are potentially subject to inaccurate recall and anchoring effects. To overcome these limitations, the method of continuous presence assessment has been applied. This method requires users to make an on-line judgment of presence using a hand-held slider. When applied to non-interactive stereoscopic media, it was found that presence ratings were subject to considerable temporal variation depending on the extent of sensory information present in the stimulus material.

Measuring BIPs is a special form of continuous presence measurement. It is special in the sense that it doesn't require a user to directly report presence, but instead a user reports the transition from being present in the virtual world to being present in the real or mental world. Having to report such a transition doesn't break the experience of presence itself since it has already been broken [11].

IJsselsteijn et al. [3] comment on a potential criticism that may be raised against continuous presence assessment, i.e., that users are in fact required to divide their attention between both the display and the on-line rating they are asked to provide, thereby possibly disrupting the presence experience. However, observers are unlikely to report on a belief of being in the displayed scene, since they are usually well aware of actually being in a laboratory. Rather, they report on a sensation of being there that approximates what they would experience if they were really there. This does not necessarily conflict with providing a continuous rating – especially given the fact that the measurement device requires very little attention or effort to operate. The need to consciously reflect on the amount of presence experienced in order to give a reliable rating is of course intrinsic to both continuous and discrete subjective measures of presence.

Another interesting psychophysical method for measuring presence to be mentioned is the method of paired comparisons, which, in the context of VR systems, has sometimes been referred to as the 'virtual reality Turing test [3]. Here, a user is asked to distinguish between a virtual and a real scene. It is suggested that the probability that a human perceives that he or she is physically present in a given virtual environment can serve as a subjective measure of presence. Since users are unlikely to confuse the real environment with the virtual one, a number of perceptual limitations are imposed on the user during the test (e.g., both the real and virtual environments have to be viewed with a limited visual field, with reduced contrast or colour, not using sound, etc.). Taking the amount of degradation of the real scene that is necessary to make it indistinguishable from the virtual one has been suggested as a measure of presence. A potential criticism that can be raised against this methodology is that it becomes a test of participants' ability to discriminate between two degraded images rather than a measure of presence.

While subjective measurement methods are effective means of assessing presence, it is important to note that such methods should be used judiciously due to inconsistencies across different raters or rating situations. Different users may apply scales differently and thus a means of calibrating individual differences may be required to control for bias [1, 3]. Relatedly, it has been shown that subjective ratings of presence can be biased by previous experience, e.g., rating a different attribute in a previous session [3]. On top of that subjective methods require users to have a fair understanding of what is meant by the term 'presence' and subjective measures can only provide conscious, voluntary, and supported responses from users while it has been shown that sometimes a user's behavior contradicts their own assessment [3, 9, 11].

4.2 Objective Measurement

The problems that are inherent to subjective measurement of presence have led to the search for objective measurement techniques. Most objective measurement methods are based on involuntary response monitoring. The nature of the involuntary response can be postural (e.g., ducking for an incoming object or a startling reaction), social (e.g., facial expressions, eye contact or gestures) or physiological (e.g., cardiovascular behavior, skin conductance or neurophysiological patterns) [3]. Both postural and social responses are dependent of a particular situation that a user experiences and are hence unsuitable as a measurement method in all VR systems. Physiological responses however might prove to be more suitable in a general sense [3, 9, 11]. Slater points out that a promising way forward may be a combination of physiological measures and BIPs [11]. If there proves to be a common physiological BIP response that is invariant and which can be isolated under many different conditions, we're in business, so to speak.

Another objective measurement method, that is consistent with the view that the allocation of attentional resources plays an important role in presence, is known as secondary reaction time measure [3]. The fundamental assumption is that as more effort is dedicated to the primary task, fewer resources remain for the secondary task. Typical results show that, when attending to the primary task, people make more errors in responding to the secondary task or take longer to respond to a cue (often a tone or a light). It may thus be hypothesized that as presence increases, more attention will be allocated to the virtual world, which would mean an increase in secondary reaction times and errors. This hypothesis has yet to be empirically investigated.

Generally speaking, the objective measure that is being used as a presence measure should be tailored to the media experience the user is intended to have [3]. A drawback to objective measures is that they tend to be "all-or-none" and, even when they are not binary, their quantitative relationship to presence may be unclear [15].

5.0 DETERMINANTS OF PRESENCE

During the past years there has not really been agreement among researchers about the concept that the term presence encompasses [15]. However, there has been speculation and empirical research concerning the determinants of presence. Researchers have tried to find evidence for things that will enhance to feeling of presence, but since the evidence has been based on varies theories and measurement methods, it is not easy to compare and categorize them. It is important to designers of VR systems to have an understanding of the relative weighting of determinants, but it is found impossible to rank the importance of a given factor for presence without specifying the situation and task under consideration. For example, if a task requires a close view of an object and fine hand-eye coordination, then stereopsis is likely to be very important for the sense of presence. However, if the task is one of driving a car along a winding road without going out of the lane, the provision of stereopsis will be irrelevant for presence. This conclusion, however, does not eliminate the need for research on the various determinants.

Moreover, most determinants have not been described in terms of the effects they have on the identified dimensions of presence, as described in the section on theories, definitions, and multi-dimensionality. For example, researchers have coined virtual world realism, action realism and presentation realism as determinants of presence, while recent insights tell us that realism is actually a dimension of presence. There have been proposed various categorizations of determinants, see for instance Schuemie et al. [8]. Here the determinants will be described along the components of a VR system.

The computer system, which is a key component of a VR system, is assumed to be working without errors. Any process interruption or failure at either computer hardware level, operating system level or at the level of the VR simulation may diminish presence [3]. In practice however, this is easier said than done; smooth, error free operation is not always easy to accomplish.

The human body, which is central to the other side of the model of VR systems, is assumed to be the body of a healthy individual with normal abilities. Any abnormalities in bodily functions or mental abilities may have strong effects on the presence that can be elicited in an individual.

5.1 Sensors and Displays

Sensors and displays have often been identified to influence presence, which is logical because they ultimately determine what kind of information can be exchanged between the virtual world and the human mind. The following aspects of sensors and displays will be discussed: coverage, richness, device characteristics, obtrusiveness and consistency.

5.1.1 Coverage and Richness

Both the coverage (the amount of different modalities covered) and richness (the amount of coverage in a single modality) of usefully displayed sensory information presented in a consistent manner to the appropriate senses of a user are often mentioned as important factors to enable presence [2, 3, 5, 9, 11, 15, 16]. It is believed that feeding richer information to the senses and adding more displays to encompass more senses result in higher presence. For example, media that provide both aural and visual stimuli are said to produce a greater sense of presence than audio-only or video-only media. It is not entirely clear which senses contribute most to presence. In general, our visual and aural senses dominate our perception and have been most often identified with presence [5]. A similar argument can be held for the coverage and richness of the sensors in a VR system, as long as the signals coming from the sensors are processed in some meaningful way and presented to the user. Adding tracking of the head and hands has indeed been identified to increase presence [3, 6, 17].

5.1.2 Device Characteristics

There has been quite some research on the effects of specific characteristics of displays and sensors on presence [3, 9, 17]. Most displays rely on a process where discrete digital signals from the computer system are converted to some continuous analogue signal, and most sensors work just the other way around. In both cases, it is necessary that the discrete signals have a sufficiently high temporal resolution (update rate), signal resolution and spatial resolution to avoid breaking the illusion of non-mediation. Each human sense has a particular range of acceptable resolutions that can be perceived meaningfully. The desired resolution is the point at which the brain perceives the discrete sensory inputs as continuous input.

Many characteristics specific to visual displays encourage a sense of presence, including image quality, image size and viewing distance (which together determine the proportion of a user's visual field occupied by an image), motion and colour, monocular and binocular depth cues, and the use of a variety of camera techniques [3, 5, 15]. The characteristics of auditory displays that are most frequently recognized to be important for presence are sound quality and spatial hearing.

5.1.3 Obtrusiveness

For an illusion of non-mediation to be effective, the medium should not be obvious or obtrusive, i.e., it should not draw attention to itself and remind the user that he or she is having a mediated experience [6]. This implies that user grounded sensors and displays should have good ergonomical features (e.g., low weight) [3, 15], and ideally there would be no cables attached to a user [17].

Glitches, distortions or malfunctions in the hardware components make the mediated nature of the experience obvious and interfere with presence [3, 5]. It is suggested that noise, broadly defined as "information that is irrelevant to the intended communication regardless of the sensory channel through which it is transmitted" discourages presence.

5.1.4 Consistency

Another determinant of presence is the consistency between information in the different modalities. Information received through the various channels should describe the same objective world. Failure to meet this criterion emphasizes the artificial and thus the mediated nature of an experience [5, 15]. For instance, Usoh et al. identified investigator location incongruity (looking at the experimenter's voice location and seeing no one) caused many BIPs [17].

5.2 Virtual World

Sherman and Craig mention that, given a compelling presentation, presence can be caused by the content of the virtual world alone [9]. For instance, immersion is not necessary when reading a novel, nor is it desired. Although this is a valid observation, it is likely only to refer to involvement rather than the other dimensions of presence. In this section the influence of situation and task, virtual world realism, transfer of object permanence and occurrence and representation of human beings will be discussed.

5.2.1 Situation and Task

Amongst the most influential determinants of presence are the situation in the virtual world (sometimes also referred to as setting or story) that has been chosen by the designers of a VR system and the task that must be accomplished (sometimes also referred to as activity or goal) [3, 5]. As Heeter points out, the type of task may make it more or less difficult to establish presence [2]. Some situations are easier to represent by a VR system than others and they may depend on hardware or software components that are not easily created or combined with other components. A significant aspect or feature of a situation that is not properly supported by the VR system, but that a user expects to be there might cause more damage to the sense of presence than it does well. Perceptually significant anomalies in the virtual world may cause BIPs. Slater states that the study of presence is concerned with what minimal set of significant features is essential for maintaining the perception of which situation the participant is experiencing [11]. It seems that some minimal set of cues is needed to establish presence in a place and that the mind fills in the gaps. Therefore, choosing a right world and situation for a certain activity often comes down to searching a situation in which as many aspects as possible can be left out from the simulation.

5.2.2 Virtual World Realism

Realism can be applied to almost every aspect of a virtual world. Realism refers to aspects that users are familiar with of the real world that are modelled in the virtual world. For instance, realistic object properties, like shape, colour, weight, texture, and so on. Or, realistic behavior (laws) like persistency, consistency, object permanency or the law of gravity which are basic concepts in our real world. On a higher level realism can even refer to structural, social, economical or political aspects that are known from our human world. For instance, social elements, such as the acknowledgement of the users through the reactions of others, virtual or real, will be important for establishing a sense of social presence [3]. The ability to affect the world directly with meta-commands may be regarded as reducing the presence of the experience, so designers generally do not allow a user to perform such an operation [9].

Storylines, characters, and acting in some media content is more realistic than in others [5]. In a dramatic film or an interactive video game, if the story makes sense and doesn't depend only on coincidence, if the characters act in consistent and understandable ways, if the actors skilfully and convincingly create their personae, the experience is more likely to "ring true" for its users. Although it has not been empirically tested, this suggests that such realistic experiences are also more likely to evoke a sense of presence. To the extent that the content "rings false" the consumer is reminded of the mediated and artificial nature of the experience and the sense of presence should be destroyed. This concept of realism has been referred to as social realism, a component of perceived realism, verisimilitude, plausibility, and authenticity and

believability. While social realism is usually applied to traditional media content, a virtual world can also contain more or less social realism: a world with a green sky, flying trains, and misshapen animals that speak Dutch would surely seem more surreal than real, and therefore would be less likely to evoke presence.

5.2.3 Transfer of Object Permanence

Like young children who don't completely learn the concept of object permanence in the real world until the age of 18 months, people entering a virtual world for the first time may have difficulty 'believing' in the permanence of objects there [9]. The addition of multiple senses corroborating the existence of an object in the world increases the believability of that object and, by extension, of the world itself. Developers can take advantage of sensory carryover to increase the impression of realness of the world. This works both to increase realism of particular objects and of the world as a whole. The more realistic an individual object seems, the more the user will expect it to behave naturally. One way to enhance realism is to make the sonic aspect of an object follow that object through the virtual space – even when it is no longer in view of the user. The result is that the participant 'realizes' that the object has a property of permanency. Likewise, the realism of the world as a whole can be improved when some of the objects are sensorially enhanced. So, when a user encounters one object that seems very real to them, the 'reality' of the other objects in the world will probably also increase. This can be very useful in helping participants overcome an initial barrier to suspending disbelief. Thus, participants' expectation of realness becomes higher, and they begin to trust the world as it is represented without testing it.

Since the haptic sense is very difficult to fool, haptic feedback that corroborates other sensory input can be particularly effective [9]. In one experiment a tracker was mounted on a physical dinner plate to produce a (passive) haptic display. The tracker on the real plate was linked to a plate representation in the virtual world. When a user is given the virtual plate and finds that it possesses all the properties of the real counterpart, he or she is more apt to extend his or her conception of realness to the rest of the virtual world. Transfer of object permanence can increase the user's suspension of disbelief to the degree that they won't attempt to walk through a wall and, thus, never discover that the walls are not as fully represented as the plate. Another experiment that exploits transfer of object permanence using passive haptics used styrofoam, foam core, and plywood located coincidentally with visual representations of walls and surfaces in the virtual world to physically mimic a portion of a virtual world. Thus, as the users see a virtual surface, and they reach out and touch it, they can feel some physical material in the proper location. When it comes to believe something is "real", the haptic sense is quite powerful. By coming into physical contact with an object, its existence is verified.

5.2.4 Occurrence and Representation of Human Beings

Another feature that may encourage a sense of presence is the number of people the user can encounter while using the VR system. Heeter suggested that "people want connection with other people more than any other experience [2]. Placing more than one person in a virtual world may be an easy way to induce a sense of presence regardless of the other perceptual features of the world". People that are represented by agents need to exhibit a range of autonomous behaviours to be believable [3].

Presence correlates highly with the degree of association with the own virtual body, the avatar [3, 17]. Avatar realism is worth a lot of work and investment, since user identification with the virtual body is such a strong factor in presence. Also, clothing identification has been identified as being surprisingly important in some studies [17].

5.3 Action

Most researchers have either implicitly assumed or explicitly suggested that a major or even the primary cause of presence is the ability to perform actions in the virtual world [5]. Often the term interaction is

used in this context, which refers to an action and its associated response. Sherman and Craig state that when the virtual world responds to our actions, we become more involved with that world, increasing our sense of presence [9].

An action requires active usage of the user's body. The real proprioceptive sensations of an action together with a presentation of any changes to the virtual world, strongly affect presence [13, 14]. Regenbrecht and Schubert suggest that interactivity should first and foremost influence spatial presence because it directly determines the meshings formed between body and the virtual world [6]. It should affect involvement only as far as it draws additional attention to the virtual world.

In this section action types, number and range, control of action, action realism and illusionary action will be discussed.

5.3.1 Action Types

Several types of actions, i.e., manipulation, travel and communication, have been identified to influence presence [15]. A sense of presence develops from the mental representation of movement of the own body (or body parts) as a possible action in the virtual world, or from the meshing of bodily actions with objects or agents in the virtual world [6].

The ability to travel, in its different forms (from flying to virtual walking to real walking about in a significant space) has widely been acknowledged to enhance presence [6, 16, 17]. Usoh et al. have shown results, suggesting that presence is higher for virtual walkers than for flyers, and higher for real walkers than for virtual walkers [17]. However, the difference between groups diminishes when oculomotor discomfort is taken into account. If one wants increased presence or a visceral estimate of spatial extents of human-scale spaces, real walking is best, and virtual walking seems clearly better than flying. Regenbrecht and Schubert write that travel as a basic possibility to interact with the virtual world has an increasing effect on spatial presence [6]. Furthermore, it increases judgments of realness. These results imply that the possibility to move oneself freely through a virtual space increases the sense of being in this space and acting in it, as well as the sense that this space is real. There was no effect of travel on involvement.

There seems to be an obvious difference between communication and the other two action types identified [4]. Communication is central to social presence, but unnecessary to establish a sense of physical presence. Indeed, a medium can provide a high degree of physical presence without having the capacity for transmitting reciprocal communicative signals at all. Use of communication with respect to virtual worlds has mostly been limited to use of voice. IJsselsteijn et al. predict that when technology increasingly conveys non-verbal communicative cues, such as gaze direction or posture, social presence will increase [3]. To perceive a technology as a social entity instead of an artificial medium, the user needs to be able to interact with it. The number of previous user inputs that are acknowledged in a response is especially important. In a different context, a computer which appears to have no memory of recent events in an interaction should be less likely to evoke the illusion of presence [5].

5.3.2 Number and Range

The number (and type) of characteristics of a VR experience that can be modified by the user also help determine the degree to which it can be called interactive. It is suggested that a highly responsive virtual world, one in which many user actions provoke even unnatural responses (e.g., entering a room produces verbal or musical greetings or rain) could evoke a greater sense of presence than less responsive environments [5] ("the more possibilities there are of interacting, the more cognitive meshings are possible, and presence increases" [6]).

Another determinant is the range or amount of change possible in each characteristic of the experience [5]. Interactivity, and perhaps therefore presence, is enhanced by expanding the degree to which users can control each attribute of the mediated experience. For example, in a highly interactive VR system the user can look in any direction, move over large distances in each direction, proceed at any pace and in any sequence desired, pick up, feel, and move many different objects each with different textures, and change the type and volume level of ambient sounds. In a different context, the larger the vocabulary of a computer speech recognition system (i.e., the more words it recognizes and to which it responds appropriately) the more interactive the experience is.

5.3.3 Control of Action

An important aspect of interaction is the amount of control that a user has over it [3]. Stanney et al. suggest that the more control a user has over their actions in a virtual world, the higher the ensuing sense of presence [15]. They report on a study that found that presence was higher for users who were in control of their own actions in the virtual world as compared to passive observers. Driving a virtual car created higher presence than merely being a passenger in it [6]. This suggests that if users are provided with a high level of user-initiated control, presence may be increased.

5.3.4 Lag/Latency

Another important factor that affects interactivity is the lag that is introduced by the accumulated processing time required by the different components of a VR system [5]. The lag determines the speed with which a VR system is able to respond to user inputs. An ideal interactive medium responds in "real time" to user input; the response or lag time is not noticeable. Noticeable lags, temporal distortions and response latency have widely been acknowledged to affect interactivity and hence presence [2, 3, 5, 8, 9, 15, 17].

5.3.5 Action Realism

The degree of correspondence between the type of user input and the type of medium response is another variable that determines how interactivity affects presence [5]. The "mapping" between these two can vary from being arbitrary (e.g., pressing a sequence of keys on a keyboard to adjust a visual display) to natural (e.g., turning one's head in a virtual reality system to see the corresponding part of the environment). The mapping between the user's actions and the perceptible spatiotemporal effects of those actions need to be consistent. For example, using head tracking, a turn of the user's head should result in a corresponding real-time update of the visual and auditory displays [3]. Lombard and Ditton write that it is a widely accepted working hypothesis that using our familiar sensorimotor skills to manipulate virtual objects directly by means of whole-hand input devices contributes to our sense of presence much more than writing programs, twisting knobs, or pushing a mouse to accomplish the same task [5].

Weghorst and Bellinghurst (cited by Stanney et al. [15]) manipulated the design of VR systems through the degree of abstractness of objects, as well as the use of a ground plane and other spatial landmarks. They found that designs that eased the interaction were most predictive of the sense of presence. This suggests that if interaction can be streamlined, interactive fidelity or presence may be enhanced.

5.3.6 Illusionary Action

An interesting experiment by Regenbrecht and Schubert shows that presence develops from the mental representation of possible bodily interactions, and not from the objective possibility to interact per se [6]. It follows that, under some circumstances, objective possibilities for interactions should not enhance presence, for example, when they are not seen or ignored, or when actions and consequences cannot be causally linked. From assuming that it is not objective possibilities to interact but perceived possibilities to

interact that determine presence, it follows that the mere illusion of an interaction should enhance presence, even when objectively no interaction takes place. Results suggest that the anticipation of possible interactions increased spatial presence. Neither involvement nor judgment of realness was influenced.

5.4 Presentation

Although designers of VR systems do not always make decisions consciously about the way in which the world is presented to a user, there have been identified some issues that can influence presence. In this section visual and aural presentation realism and use of conventions will be discussed.

5.4.1 Visual Presentation Realism

Several researchers have emphasized the relationship between presentation realism and presence [15, 17]. For instance, visual presentation realism has been mentioned to enhance the sense of presence (although the level of action control turned out to be more important). It has even been suggested that any VR experience must be extremely realistic for it to be able to give a sense of presence. Anything that demonstrates that you are not in the real world will result in a BIP.

On the other hand, various papers suggest that presence is possible in experiences where visual realism is not a factor. In such cases, other factors, such as the interaction with the game or the story, keep users engaged. For instance, books, which have very limited visual realism, effectively engage our minds and imagination [15]. Additionally, it has been shown that cartoonishness of a rendered virtual world doesn't prevent users to become present. Attempts to render a world in a photo-realistic way can even make presence difficult, because any flaw in the realism will spoil the effect [9]. However, anomalies in an environment are not equal in their significance: some will induce a BIP, and others won't. For example, in the depiction of a virtual human, an anomaly in overall body shape is likely to be far less significant than the shape and movements around the eyes and mouth [11].

Despite these seemingly contradictory points-of-view, this dispute about the necessity of visual fidelity to experience presence seems to fit well with the multi-dimensional view of presence, where realism is separated from involvement and spatial presence.

5.4.2 Aural Presentation Realism

Similar argumentation as with visual presentation realism may be held for aural presentation realism. Aural realism of virtual spaces requires replicating the spatial characteristics of sounds like the changing intensity of a race car engine as it approaches a listener and screeches past (Doppler effect), or the tapping of footsteps as they echo in a dark, empty corridor; or the chatter of a conversation off in the corner of a room [5]. It is argued that sound greatly enhances the participant's ability to become present in the world. Sound is compelling. From ambient sounds that give cues to the size, nature and mood of the setting to sounds associated with particular objects or characters nearby, aural presentation is said to be the key to user understanding and enjoyment [9]. The volume (loudness) of audio stimuli may also have an impact on presence, with particularly low and perhaps particularly high levels less effective than moderate ("realistic") levels. It has been suggested that the proper use of ambient sounds and music can evoke an atmosphere or sense of place, thereby heightening the overall feeling of presence in the virtual world [5].

Computer-based technologies increasingly present information to users with voices (either recorded human voices or computer-generated ones). The use of voice is a potent social cue and has been shown to elicit perceptions that one computer is made up of multiple distinct entities and to evoke gender stereotypes [5]. It seems likely that voices that sound more human (with higher audio realism) enhance the illusion of social presence.

5.4.3 Use of Conventions

One way in which users are reminded of the true nature of their experience is through the use of conventions that users have come to associate specifically with mediated presentations and experience [5]. In movies and television when the passage of time is represented by spinning hands on a clock, when the transition to a dream or flashback is represented with a distorted dissolve between images, when dramatic or emotional background music telegraphs the end of a segment, when credits and other text messages are superimposed over story action, when identification logos appear in the corner of the screen, when an unseen narrator describes events, and when plots and dialogue follow predictable formulae, the media user is reminded that rather than having a non-mediated experience he or she is watching something created and artificial. This realization is likely to interfere with a sense of presence.

5.5 Human Mind

There are many aspects of the human mind that are likely to play a role in presence, which is not surprising because presence itself is a subjective experience caused by processes of the human mind [3]. Characteristics that are thought to influence presence include the user's perceptual, cognitive and motor abilities (e.g., stereoscopic acuity, susceptibility to motion sickness, concentration), prior experience with and expectations towards the mediated experiences, and willingness to suspend disbelief. Allocating sufficient attentional resources to the mediated environment has also been proposed as an important component of presence. Relevant individual characteristics will possibly vary with age and sex of the user. It is likely that various mental health conditions, like depression, anxiety, or psychotic disorders, are also likely to affect an individual's sense of presence, since they are known to have a clear effect on how people experience the world around them.

5.5.1 Individual Characteristics / Personality Type

Sensory dominance is an important variable that affects depth of presence [13]. There are three different types of sensory dominance: Visual, auditory or haptic learners. The depth of presence is related to the users' innate sensory dominance and the type of feedback given by the VR system. For applications focused on visual feedback, the visually oriented person will experience more presence than the auditory oriented person. In a virtual world without sounds, aurally dominant users felt less present. For kinaesthetically oriented users, use of an avatar in the virtual world resulted in more presence.

Lombard and Ditton give a list of characteristics of an individual that may influence presence, including age, gender, sensory dominance, cognitive style, degree to which a user "screens" complex stimuli, level of sensation seeking, need to overcome loneliness, introversion/extroversion, locus of control, dominance/ submissiveness [5].

5.5.2 Willingness to Suspend Disbelief

An identical VR system with the same virtual world might generate a sense of presence in one user and not in another, or might generate presence in the same user on one occasion, but not on another one [5]. Although almost no research has been conducted on the issue, it seems clear that characteristics of users are important determinants of presence. One variable that is likely to be especially important in this regard is the user's willingness to suspend disbelief.

A person participating in a VR experience has chosen to engage in the activity and knows that it is a mediated experience [5]. He or she can encourage or discourage a sense of presence by strengthening or weakening this awareness. If we want to increase a sense of presence for ourselves we try to "get into" the experience, we overlook inconsistencies and signs that it is artificial, we suspend our disbelief that the experience could be non-mediated. When we want to decrease presence, as when we watch frightening or disturbing media content, we remind ourselves that "this isn't really happening, it's only a movie, game,

etc." The willingness to suspend disbelief probably varies both across individuals (e.g., some people are so naturally curious about how a medium works that they simply can not suspend disbelief and enjoy the experience) and within the same individuals across time (e.g., it may be more difficult to suspend disbelief and escape to a mediated world when one is preoccupied by problems at home or at work).

5.5.3 Attention

How sharply users focus their attention on the virtual world partially determines the extent to which they will become involved in that environment and how much presence they will experience. Witmer and Singer suggest that as users focus more attention on the stimuli from the virtual world, they should become more involved in the experience, leading to increased presence [19]. Attention and thus involvement depend on the significance or meaning that the individual attaches to stimuli, activities, or events [15]. The world has to be personally meaningful. If the participant does not find the topic or style in which the content is conveyed absorbing, there is little hope of engagement [3, 9]. This argument for the importance of attention in sense of presence is similar to the concept that the experience of presence is based on attention to the continuity, connectedness, and coherence of the stimulus flow [15]. Distractions that draw the user's attention from the virtual world to the real world are likely to diminish the user's sense of presence [3].

5.5.4 Mood

The experience of presence is so much affected by the state of mind (mood) of the user that anything that affects the user's subconscious mind may affect how the experience is perceived [9]. For example, the venue, or setting in which the VR system resides, can have a great impact on how an event is experienced, because the venue is part of the whole experience. The venue puts the participant in a certain state of mind when entering the virtual world, although an individual may experience the same application in the same venue differently on different days. A primary effect of ambient sounds is generally used to set the mood of an experience, which can have the effect of making the experience more compelling, increasing presence.

5.5.5 Knowledge, Prior Experience and Expectations

It should be easier for users unfamiliar with the nature of a VR system and how it functions to experience presence [5]. An engineer can not help but notice flaws in a virtual world or the image in a VR display because he or she either knows or wants to know what is responsible for the flaw. This knowledge reminds him that the experience is mediated. The situation is analogous to a magician who knows how a trick is performed and is therefore unimpressed with the illusion.

Closely related to this is the effect of experience with a medium [5]. The first time a person uses a system capable of generating a sense of presence, he or she is unfamiliar with the system, how it is used, and the nature of the experience. This unfamiliarity likely discourages a sense of presence, but as the user becomes more expert at using and manipulating the experience and more comfortable with it in general, this effect should fade. Continued experience may then either increase presence ("having 'been there before' helps you believe you are there again"[2]) or decrease it as the well-known habituation effect causes an initially impressive and novel sense of presence to fade as users become more experienced.

Extended exposure may increase presence because it enhances other factors thought to be related to presence, including the amount of practice with tasks, the familiarity with the virtual world, and the level of sensorial adaptation to the intersensory and sensorimotor discordances presented by the displays, but exposure and presence could also be negatively related [15]. Thus, it is uncertain whether long-duration exposure will enhance presence by engendering familiarity or reduce presence due to adverse side effects.

It matters what the users expect of the environment, and what they have in mind in terms of anticipations, goals, and experiences. These variables influence how they mentally construct the environment in terms of possible actions in it, and therefore these variables influence the sense of presence. Pausch et al. (cited by Regenbrecht and Schubert [6]), having observed the reactions of thousands of guests at a Disney installation, state that they can improve the experience by telling a pre-immersion background story and by giving the guest a concrete goal to perform in the virtual environment."

6.0 CONCLUDING REMARKS

It has taken some time for researchers to reach consensus about the concept that presence encompasses. One reason for this is that there are so many ways to look at it, for instance from a philosophical, psychological, neurobiological or technical perspective. Another reason is that presence is inherently subjective, and comparing experiences has proven to be very difficult. However, there seems to be convergence in the views on presence that are presented in the stream of scientific publications, both on theoretical as well as empirical issues. An important insight is the multi-dimensionality of presence. Presence can be differentiated into social presence and physical presence, of which the latter can be differentiated further into spatial presence, involvement and realism. The next step forward would be insight into the relative importance of all determinants of presence distinguished.

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